

INVESTIGATION OF FACTORS PRODUCING A SENSE OF VIRTUAL REALITY USING SUBSTITUTIONAL REALITY

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ABSTRACT

Substitutional reality (SR) technology blurs the boundary between the real and the virtual by unnoticeably substituting past images for live images. In this study, we further investigated such factors, and conducted experiments to verify whether they were indeed effective factors in SR. In the verification experiments, the subject was presented with an image in which two persons appear, wearing head-mounted displays (HMDs) and are photographed in advance; after which it was explained that one person was in a live image and the other in a past image, and the subject was asked which one the live image was. In the case where the psychological / social distance was reduced by performing cooperative action to imitate the action of the opponent, when the line of sight matches with that of only one person; and in the case of two patterns, when one person goes in and out of the personal space and does not shake or wave their hand; these three factors were verified. In the comparative experiment, the same past / live image content as in the verification experiment was employed. The results suggested that it is ineffective to conduct cooperative actions to reduce the psychological and social distance, and to enter and exit the personal space without waving. And further, it is effective when the gaze matches and when the personal space is entered / left with a hand wave. In sum, it was found that SR reality can be enhanced by adding communication.

Keywords: *substitutional reality, virtual reality, head mounted display, communication*

1. Introduction

In recent years, Augmented Reality (AR), Virtual Reality (VR), Mixed Reality (MR), Substitutional Reality (SR), and other forms of similar technology are increasingly being put into practical use. SR is a technology that blurs the lines between reality and virtual, as it switches in and out of past footage that was filmed previously, without being noticed. While VR awaits advancements in video technology to reduce the gap between reality and virtual, SR is attracting attention as a system that can provide a sense of reality and presence through a method other than video technology.

Because SR enables the user to experience the experiences of others, it is expected to be applied in a wide range of fields, such as in the medical field, where doctors can better understand the sensations of dementia and schizophrenia by experiencing them, the field of video games and entertainment, and toward previously impossible experimental methods for Kansei science and cognitive psychology [1]. In SONY's event to exhibit their new HMD, attempts have already been made to clear away the barrier between watching and experiencing the world views of movies using cognitive psychology tricks [3]. However, this type of research only relates to the effects of using SR, and there has not been much research that verifies which factors have an effect and how. Accordingly, this research has investigated the factors regarding the application of SR and verified whether or not they can be used practically, in order to verify whether or not they are effective factors for SR.

2. Research Method

2.1. Investigation of Factors

After investigating factors that were considered to be effective for SR through prior research, we focused on 2 factors. The first is that when the psychological and social distance to the other party is closed through concerted actions, such as deliberately flattering the other party's actions, the impact that you receive from the information from the other party, such as from their actions, will be stronger [3][4]. The second is that when experiencing SR, the act of characters repeatedly entering and exiting personal space of roughly 1.2m by 2m serves as an interaction with reality, allowing the user to get used to reality through the HMD [3]. We conducted verification experiments on these factors.

2.2. Development Environment

In this research, VR footage was developed through Unity 5. As shown in figure 1, panoramic footage was attached to a sphere, and we enabled the user to see 360 degrees around them, as they do in reality, by looking at the footage from the center of the sphere.

To show the VR footage, we used HTCvive, the HMD made by HTC. In addition, the 360 degree

panoramic video was filmed using a camera called THETA S made by RICOH.

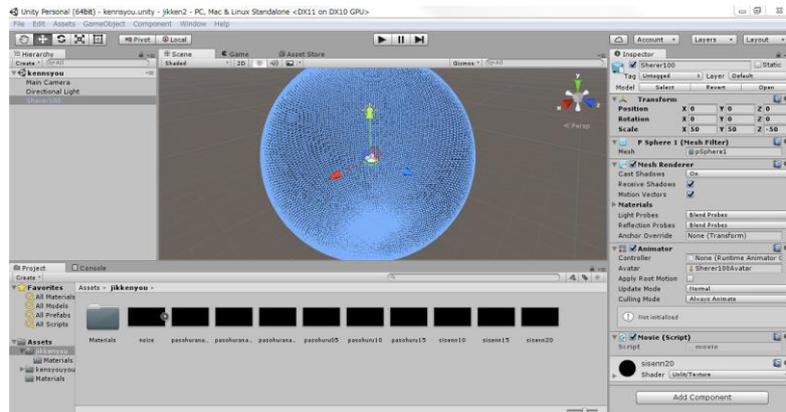


Figure 1: Screen of the development environment

3. Experiments on the Effect of Concerted Actions on Psychological and Social Distance

3.1. Experiment Outline

Through prior research, it has been made clear that when the psychological and social distance from the other party is closed through concerted actions, such as deliberately flattering the other party's actions, the impact that you receive from the information from the other party, such as their actions, will be stronger [3][4]. Accordingly, in this experiment we focused on the fact that the impact of the information received from the other party becomes stronger, performed concerted actions through VR, and conducted verification research to clarify whether the characters that have closed the psychological and social distance will be recognized as characters from reality.

3.2. Experiment Method

In order to produce the video for the experiment, footage of characters entering the experiment room from the entrance, lining up in front of the test subject, performing actions for roughly 20 seconds, and leaving through the exit was filmed using THETA S. Characters were filmed one at a time, and the footage was edited so that the characters would appear as 2 at a time before being seen through the HMD. Test subjects wore the HMD and headphones as shown in figure 2.



Figure 2. Image of the HMD being worn

When beginning the experiment, we explained to the test subjects that one of the characters is live footage, while the other character is past footage that was filmed in the past. When the movements of the 2 characters were the same, we had the test subject mimic the character that they selected, and when the movements of the 2 characters were different, we had the test subject mimic the movements of the character we specified. For the characters, there were the 3 variations of footage where the characters are different, footage where the characters are the same males, and footage where the characters are the same females, and for the movements, there were the 2 variations of the same movements and different movements, resulting in 6 total variations. From the headphones, we played footsteps that matched the footage, making it impossible to make a determination based on the sounds.

The concerted actions were to open and close the arms to the side of the body, where it is difficult for the hands to come into peripheral view without moving the head. Also, surveys were conducted for each trial before and after the experiment, and test subjects were asked which of the 2 characters they believed were from live footage and why, among other questions. The test subjects were made of 20 university students in their 20s, and the experiments were conducted in the room that the footage was filmed.

3.3. Results and Observations

As a result of computing the ratio of test subjects who determined that the character for whom they mimicked movement was the live footage for each trial, the maximum was 65% and the minimum was 40% for the 6 trials. This shows that there is not a clear trend that the character for whom movement was mimicked tends to be believed to be from reality, and it can be interpreted that there is not a clear trend that closing the psychological and social distance through concerted actions does not lead to believing that the character is from reality.

As for reasons that the test subject selected the character that they believed to be from reality, many responses were given that, "I felt awkwardness or roughness in picture quality for the character on the right" or, "I felt eye contact." From the responses test subjects believed characters with whom they made eye contact to be from reality, it can be thought that there is a possibility that eye contact will serve as a factor that provides a sense of reality.

4. Verification Experiment for the Usefulness of Eye Contact and Personal Space

4.1. Experiment Outline

During the experiment to investigate the impact of concerted actions, there were responses that, "We made eye contact" regarding the reason for selecting the character that they believed to be from reality. Also, prior research states that when experiencing SR, the act of characters repeatedly entering and exiting personal space of roughly 1.2m by 2m serves as an interaction with reality, allowing the user to get used to reality through the HMD [2]. Accordingly, in this experiment, we conducted verification experiments to clarify whether characters who make eye contact or characters that enter and exit personal space will be recognized as characters from reality.

4.2. Experiment Method

Similar to the previous experiment, we had the test subjects wear the HMD and headphones, look at footage where the same character appears twice, and determine which character is from reality.

Because the footage would be distorted if the line of sight is shifted due to differences in height, we used an adjustable height chair to make sure that the test subject's line of sight would be equivalent to the position of the camera at the time of filming. Also, we played noise through the headphones to prevent the footsteps from being a factor, and set the distance between the 2 characters and the fluorescent light to be equivalent to prevent a difference in brightness.

Under the same experimental environment, we conducted a preliminary experiment in order to verify whether the gaze can be felt by the direction of line of sight or the distance. As a result, by moving the face and the eyes together, it was felt that the gaze could match when the line of sight was directed or not directed, regardless of the distance. Therefore, regarding the footage used for this experiment, for the footage related to eye contact, 2 experimenters appeared simultaneously (the same character), lined up in front of the test subject, each facing their face and eyes together in various directions, and one character looked toward the test subject 5 times during each trial. For the distance that the character stands from the test subject, there were the 3 variations of 1.0m, 1.5m, and 2.0m. For the footage related to personal space, 2 characters lined up in front of the test subject, and one character approached the test subject

while moving back to front, while the other character did not approach the test subject while moving side to side. For the character moving back to front, there were 3 variations of the closest distance of 0.5m, 1.0m, and 1.5m, and there were the 2 variations of the character waving a hand or not waving a hand for a total of 6 variations. Surveys were conducted for each trial before and after the experiment, and test subjects were asked which of the 2 characters they believed were from live footage and why, among other questions. The test subjects were made of 20 university students in their 20s, and the experiments were conducted in the room that the footage was filmed.

4.3. Results and Observations

For the trials related to eye contact, the ratios of test subjects who believed that the character with whom they made eye contact was from reality for each distance were 55% for 1.0m, 75% for 1.5m, and 25% for 2.0m.

At a distance of 1.0m, 30% of test subjects responded that they did not make eye contact. The reason for this can be thought to be that when the distance between the test subject and the characters is close, it is difficult for both characters to be in the test subject's peripheral view simultaneously, so the test subject could not see the character when they were supposed to be making eye contact.

The ratios of test subjects who believed that they made eye contact with both characters were 5% for 1.0m, 0% for 1.5m, and 60% for 2.0m. The ratio of test subjects who believed that they made eye contact with both characters was clearly higher for a distance of 2.0m. The reason for this can be thought to be that the gaze of the virtual character looking in the vicinity of the test subject could be perceived as making eye contact when the distance between the test subject and the virtual character is far. The fact that there was not a clear trend for which character the test subject believed was from reality, as 40% thought that the character on the right was from reality and 60% thought that the character on the left was from reality, can also be thought to be because there were many test subjects who believed that they made eye contact with both characters.

Excluding the 1 test subject who believed they did not make eye contact at a distance of 1.5m, 79% of test subjects thought that the character that they made eye contact with was from reality. Also, excluding the test subjects who believed that they did not make eye contact at a distance of 1.0m, 78% of 1.5m test subjects thought that the character that they made eye contact with was from reality. Therefore, feeling that eye contact is made can be thought to be a factor that provides a sense of reality.

For the trials related to personal space, the ratios of test subjects who believed that the character who enters and exits personal space was from reality for each distance were 55% for

0.5m, 60% for 1.0m, and 50% for 1.5m when the character did not wave a hand, and 75% for 0.5m, 60% for 1.0m, and 60% for 1.5m when the character waved a hand. Also, the average 5-step rating of how unpleasant it was when the character approached, with 1 being most unpleasant and 5 being least unpleasant, for each distance were 3.80 (S.D.: 0.98) for 0.5m, 4.00 (S.D.: 0.89) for 1.0m, and 4.15 (S.D.: 0.91) for 1.3m when the character did not wave a hand, and 4.10 (S.D.: 0.83) for 0.5m, 4.25 (S.D.: 0.77) for 1.0m, and 4.10 (S.D.: 0.83) for 1.5m when the character waved a hand.

The ratios of test subjects who believed that the character who entered and exited personal space were from reality are listed in table 1, and the results of a t-test for each distance are listed in table 2.

Table 1. Ratio of test subjects who thought the character was from reality in personal space experiment

	0.5m	1.0m	1.5m
Did not wave a hand	55%	60%	50%
Waved a hand	75%	60%	60%

Table 2. T-test results for each trial for personal space

$p < 0.05$	0.5-1.0m	0.5-1.5m	1.0-1.5m
Did not wave a hand (p value)	0.104	0.015	0.186
Waved a hand (p value)	0.083	1.000	0.083
Yellow: Significant difference White: No significant difference			

In both trials for characters who did and did not wave a hand, for the farthest distance of 1.5m, the distance between the test subject and the character who moves side to side and the character who enters and exits personal space (1.5m – 2.0m) was hardly different and can be thought as the reason why the ratio of test subjects who believed that the approaching

character was from reality is the lowest value. Also, out of the 6 trials, a relatively high ratio was the 75% for the conditions of waved a hand and a distance of 0.5m. It can be thought that within the ranges set up in this experiment, the entry and exit of personal space at the closest distance provides a sense of reality.

For the 3 trials where the character did not wave a hand, the highest ratio was 60%, so it can be thought that simply entering and exiting personal space is not enough to provide a sense of reality. Also, the highest ratio of test subjects who believed that the character who waved a hand was from reality is 75%, which is a higher result than for the character who did not wave a hand. This can be thought to be because the action of waving a hand in addition to entering and exiting personal space provided a sense of familiarity to the test subject.

In the 3 trials where the character did not wave a hand, the distance of 0.5m was felt to be most unpleasant, and there was a significant difference between the closest distance of 0.5m and the farthest distance of 1.5m. The reason for this can be thought to be that the virtual character repeatedly approaching without any expression provides a sense of fear and tension, resulting in an increased sense of unpleasantness when the character came within 0.5m. Also, in the 3 trials where the character waved a hand, there was no significant difference between the distances. The reason for this can be thought that the sense of unpleasantness was reduced because familiarity was created by waving a hand.

Based on the above, it can be thought within this experiment's conditions that in addition to entering and exiting personal space by approaching within 0.5m of the test subject, interacting with the test subjects by waving a hand or other actions provides a sense of reality.

The conditions that provided a sense of reality are making eye contact and entering and exiting personal space while waving a hand, which are both actions of communicating, so it can be thought that communication plays an important role as a factor that provides a sense of reality. Also, due to the fact that even within the condition of entering and exiting personal space, the condition of waving a hand, which is a form of communication, had a higher ratio of being thought to be from reality than the condition of not waving a hand, even for factors that cannot provide a sense of reality, it can be thought that adding a form of communication can provide a sense of reality.

5. Conclusion and Future Tasks

In this research, investigations were conducted with the objective of discovering factors that make the virtual in SR made believed to be reality and evaluating whether the factors can be used practically.

Through the verification experiments regarding whether characters who closed the

psychological and social distance through concerted actions would be considered to be from reality, it became clear that closing the psychological and social distance through concerted actions has a low likelihood of providing a sense of reality.

Through the verification experiments regarding whether characters who make eye contact and characters who enter and exit personal space would be considered to be from reality, it was found that sensing eye contact has a possibility of providing a sense of reality. Also, for the entrance and exit of personal space, it was found that approaching within 0.5m while waving a hand also has a possibility of providing a sense of reality.

Concerted actions and entering and exiting personal space are not enough to provide a sense of reality, but making eye contact and simultaneously waving a hand while entering and exiting personal space were effective. Therefore, it was found that adding actions of communication can provide a sense of reality.

As the brightness had an impact on the experiments with concerted actions, there were various effects other than the factors contained in this research, such as the impact of the picture quality and sound of the experiment footage due to the environment of the experiment room and the impact of the familiarity between the character in the footage and the test subject for the personal space experiment. There is a necessity to perform the experiments after thoroughly eliminating the impact of other factors and experiments that verify which factors have an impact. In these experiments, verification was only performed for human characters, but there is a necessity to formulate new experiment methods to verify whether the findings are applicable for non-human characters and concepts that do not exist in reality (such as cartoon characters).

Reference Documents

Wakisaka, S. (2013). Substitutional reality system as an experimental platform of internal measurement. *The 27th Annual Conference of the Japanese Society for Artificial Intelligence*.

Wakisaka, S., & Fujii, N. (2012). Sense of reality and presence in substitutional reality systems. *The Institute of Image Information and Television Engineers Technical Report, 36(44)*, 19-23.

Takahashi, K., & Watanabe, K. (2008). Interpersonal synchrollization in unconscious hand movement. *IEICE Technical Repot, HIP, Human Information Processing, 108(282)*, 111-116.

Watanabe, K., & Takahashi, K. (2013). Cognitive Science and Emergence of Presence. *The journal of the Institute of Image Information and Television Engineers 67(4)*, 289-292.